Effect of Lime and Clay on engineering behavior of Quarry Muck

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Abstract— *Stabilization is most effective and economic way of improving engineering properties of soil. Several methods are available to improve the engineering behavior of soil. In this paper, the effect of stabilization of lime and clay on quarry muck is studied. The quarry muck is generated as by-product from quarry. The use of such industrial wastes in engineering application will result in added benefit because such wastes are not only causing environmental problems, but are also causing serious problems for their disposal, on account of shortage of land. Here the quarry muck is stabilized with lime and clay in different proportions to form mixtures and their compaction characteristics, unconfined compressive strength were determined. With the help of these parameters, the optimum percentage of lime and clay with quarry muck were evaluated in order to use them as a sub grade for construction purposes. The effect of stabilization of three different lime ratios (1, 3 and 5% by weight of dry quarry muck) and three different clay ratios (5, 10 and 15% by weight of dry quarry muck) are studied in this paper.*

Keywords— Stabilization, Compaction, Strength, Direct shear

I. INTRODUCTION

It is evident that construction projects require soils with sufficiently good engineering properties. However, it is difficult to find suitable sites for construction or suitable material for different construction projects within an economic range. Unsuitable materials with poor engineering properties are frequently encountered and hence it is necessary to improve their properties to make them acceptable for construction. Improvement of soil properties or soil stabilization is a technique introduced with the main purpose of rendering the soils capable of meeting the requirements of the specific engineering projects.

In different countries waste materials have been used as backfilling material and as aggregates in different construction environment in a limited amount and any new method of use having additional value has not been developed. Previous work in stabilization of clayey soils with lime has shown that small amounts of lime considerably improve workability but contribute little to strength, whereas larger amounts of lime also improve the strength and bearing capacities of these soils. In this context, the possibility of usage of quarry muck as a ground improvement material obtained by mixing with clay and lime is being investigated.

The addition of stabilizers to soils to improve their use for construction purposes has a very long history. Quarry muck is a waste material and is generated as by product from quarry. Disposal of these type of materials are creating severe problems to the environment. Muck reuse is always an environmental benefit, since it reduces both disposal in landfills and raw material extraction, whatever the type of civil work concerned.

In this study, lime is used as binding material in small amount to increase the strength of the quarry muck satisfactorily. Lime is nothing but Calcium oxide or Calcium hydroxide. A study conducted by Ogundipe and Moses, (2013) [16] refers to the hypothesis that when lime reacts with the soil, there is exchange of cations in adsorbed water layer which results in decrease in plasticity of soil. The lime is more friable and it is more suitable to use in subgrade. Some clay contents are added to the lime, then the chemical reactions are observed and their effectiveness is noted.

The present investigation is an attempt to stabilize quarry muck with the aid of lime and clay. Standard Proctor test, unconfined compressive strength test, in addition to some preliminary tests was conducted for assessing the stability of lime-clay mix with quarry muck. Laboratory test results present the influence of different mix properties of lime and clay on California Bearing Ratio and strength parameters of quarry muck.

II. MATERIALS AND METHODOLOGY

A. Quarry Muck

Quarry muck to be used was selected from a quarry nearby Kilimanoor and was pulverized repeatedly until all soil aggregations were reduced to particle size through appropriate mesh sieve. Then sieve analysis was done which revealed that the percentage of sand in the mixture was 97%. In order to remove the moisture content, the mixture was air dried and stored until needed. The properties of quarry muck collected are presented in Table 1. Quarry muck used is shown in Fig. 1.

Fig. 1: Quarry muck

Properties	Value
Specific Gravity	2.5
MDD (g/cc)	1.56
OMC (%)	21.4
Sand (%)	97.1
Effective size, D_{10} (mm)	0.16
Uniformity Coefficient, Cu	3.125
Coefficient of curvature, Cc	1.125

Table 1: Properties of Quarry muck

B. Lime

Lime is a derivative of limestone and is extracted from quarries and underground mines all over the world. It consists of high levels of calcium and magnesium carbonate. Several types of lime are available but the most widely used for engineering purposes are quicklime (CaO) and hydrated lime (Ca $(OH)_2$). Here Quicklime is used which is formed by burning limestone and comprises the oxides of calcium and magnesium.

The commercially available quick lime was used for the study. It was used as a chemical additive. The proportion of lime added to the soil was 1%, 3% and 5%.The chemical and physical properties of lime are given in Table 2. Quick lime used is shown in the Fig. 2.

Fig. 2: Lime

Properties	Value
Physical Appearance	Dry white powder
Specific Gravity	2
Insoluble Material (%)	<1
Bulk Density (g/l)	600-900

Table 2: Properties of Lime

C. Kaolinite Clay

Kaolinite is a clay mineral, has low shrink-swell capacity and a low cation exchange capacity. In order to improve the engineering behavior of quarry muck, several improvement techniques are available in geotechnical engineering practice to study the change the effect of quarry muck treated with kaolinite clay and lime.

The clay used in this study is of kaoilinite type. It was collected from English India Clay Limited, Thonnakkal, Trivandrum. Clay was added in the proportion of 5%, 10%, 15% into the mixture. The properties of the clay used are listed in Table 3 below. Kaolinite clay is shown in the Fig. 3.

Fig. 3: Kaolinite Clay

Properties	**Value**
Specific Gravity	2.1
Liquid Limit (%)	40
Plastic Limit (%)	23
Plasticity Index (%)	17
Shrinkage Limit (%)	15
OMC (%)	32
MDD (g/cc)	1.36
UCC (kg/cm^2)	0.426

Table 3: Properties of Kaolinite Clay

D. Specimen Mixes

To study the possibility of quarry muck as a subgrade material and its utilization in geotechnical applications, a total of 9 different mixes were prepared using different percentages of clay and lime. The different specimen mixes used in this investigation has been listed below in Table 4.

No	Mixes
1	S
2	S+1%L+5%C
3	S+3%L+5%C
4	S+5%L+5%C
5	S+1%L+10%C
6	S+3%L+10%C
7	S+5%L+10%C
8	S+1%L+15%C
9	S+3%L+15%C
10	S+5%L+15%C

Table 4: Specimen Mixes

Here 'S' represents quarry muck sample, 'C' represents clay and 'L' represents lime.

E. Methodology

This study involves the collection of quarry muck sample from a quarry area near Kilimanoor and evaluation of its properties in natural state and after stabilization with lime and clay. The major objective of the study is to determine the optimum lime and clay content that will stabilize the quarry muck adequately. Also, it investigates the level of improvement that could be achieved by stabilizing clayey soil with lime. The experiment was conducted in the following steps.

1) Determine the initial properties of quarry muck.
2) Varying percentages of Clay (5%, 10%, 15%) and Lime (1%, 3%, 5%) has been added to quarry muck in different proportions to form 9 unique combinations of the mixture.
3) Determine optimum content of clay and lime by conducting standard proctor compaction test.
4) Prepare UCS – samples with optimum values of admixtures obtained from compaction test at OMC (Optimum Moisture Content) and MDD (Maximum Dry Density)
5) Conducting CBR tests on un-stablilized and lime-clay stabilized samples.
6) Determined the shear strength parameters of stabilized samples.

From the literatures it has been found that, no studies has been conducted for utilization of quarry muck in geotechnical applications. The possibility of quarry muck as a subgrade material was not studied. The effect of stabilization of lime and clay with quarry muck for an effective reuse strategy for quarry muck has been studied and evaluated in this experimental study and the results of these evaluations are listed out in the next chapter.

III. RESULTS

A. Standard Proctor Compaction Test

Standard compaction test method is performed to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the sample. The test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density. The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density. These laboratory tests generally consist of compacting soil at known moisture content into a cylindrical mould of standard dimensions using a compactive effort of controlled magnitude as per BIS: 2720 (Part 8)-1983.

The results obtained from different mixes of lime and clay shown in Fig. 3.1, 3.2 and 3.3, shows that as the percentage of lime increases the Maximum Dry Density (MDD) reduces with increase in clay content. The Optimum Moisture Content (OMC) also slightly increases with increase in clay content. A study conducted by Alrubaye, (2016) [4] suggested that as the lime content increases, more calcium ions are released resulting in more flocculation and agglomeration of clay particles. This flocculation produces change in the texture of clay soils. The clay particles form larger particles with large void spaces between them culminating into lower maximum density. The decrease in maximum dry density of the lime treated soil is a reflection of increased resistance offered by the flocculated soil structure to the compacted effort. It was also believed that optimum moisture content increased with increasing lime and clay content because more water was needed for the chemical reactions between lime and clay.

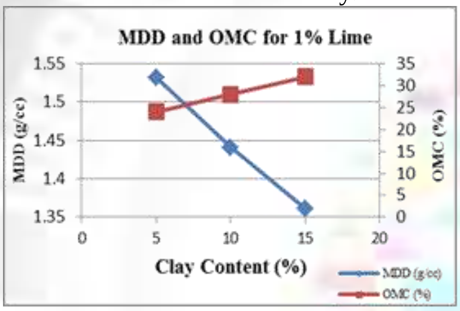

Fig. 4: MDD and OMC for 1% lime and varying percentage of clay with quarry muck

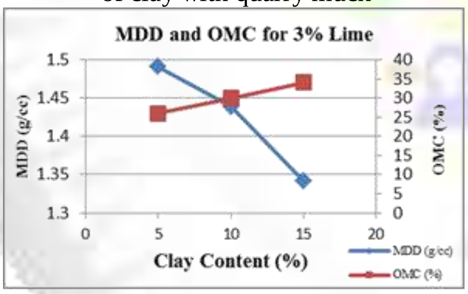

Fig. 5: MDD and OMC for 3% lime and varying percentage of clay with quarry muck

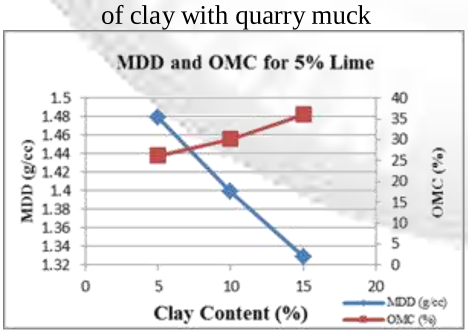

Fig. 6: MDD and OMC for 5% lime and varying percentage of clay with quarry muck

B. Un-confined Compressive strength test

Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size. In normal circumstances, the sample cannot be prepared as the percentage of sand in quarry muck was 97.1%. On addition of water sticky behavior was shown by the quarry muck which helped in preparation of the sample. UCS test conducted on quarry muck sample yielded the result as 0.783 kg/cm^2.

Each specimen used in the unconfined compressive strength test was compacted in a cylindrical mould at optimum moisture content and maximum dry density. Specimens were cured in a plastic bag to prevent moisture change. Tests were performed at different curing ages (0, 7 and 14 days). The results of the unconfined compressive strength is obtained and plotted at different curing periods. Figures 3.4 to 3.12 shows the effect of varying percentage of lime and clay content with quarry muck at 0, 7 and 14 curing days respectively. The unconfined compressive strength of each specimen is determined based on the peak strength of stress versus strain curve.

In case of 0 curing days, the unconfined compressive strength was found to be increasing on 3% lime treatment and then it was considerably decreased on further addition of lime. For 7 curing days, a steep decrease in compressive strength values is observed on 1% lime treatment on increasing percentages of clay. An increase of 3% and 5% lime resulted in a considerable increase in the compressive strength values followed by fluctuating decrease and increase in values as the clay content increases. On 14 days of curing, it was observed that 3% lime treatment with 5% clay for quarry muck results in maximum strength value of 6.253 kg/cm^2 resulting in 3.886 times increase in the strength of un-cured soil.

In general, the overall results shows that unconfined compressive strength increases as the curing period increases for all the samples tested in this study. The initial increment of unconfined compressive strength might be due to the hydration of lime in the sample and the later decrement of unconfined compressive strength might be due to the presence of excess lime (having less compressive strength) in the sample. It was also clear from the analysis that 3% lime and 5% clay content in quarry muck gives highest unconfined compressive strength at each curing period used in this study.

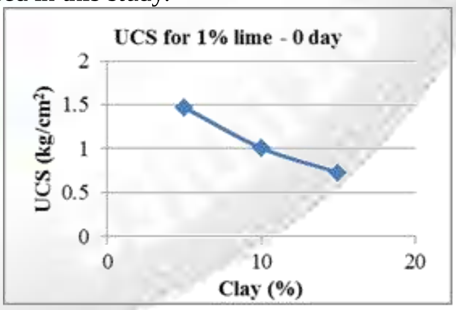

Fig. 7: UCS values for 1% lime and varying percentage clay with quarry muck.

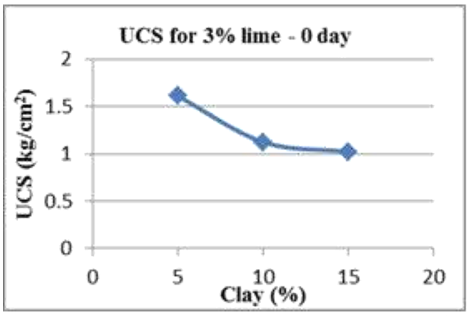

Fig. 8: UCS values for 3% lime and varying percentage clay with quarry muck.

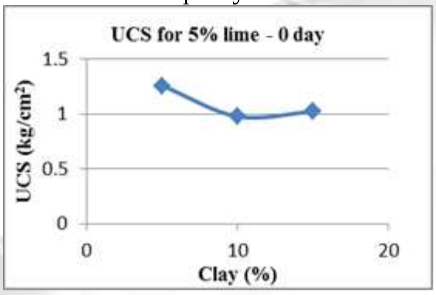

Fig. 9: UCS values for 5% lime and varying percentage clay with quarry muck.

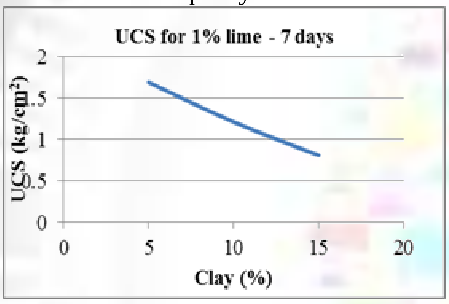

Fig. 10: UCS values for 1% lime and varying percentage clay with quarry muck for 7 days curing period.

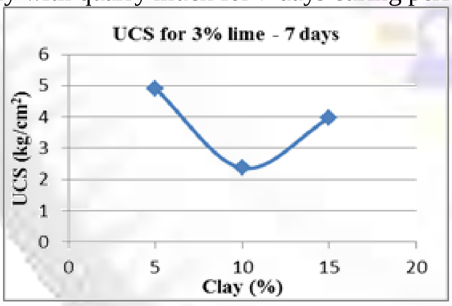

Fig. 11: UCS values for 3% lime and varying percentage clay with quarry muck for 7 days curing period.

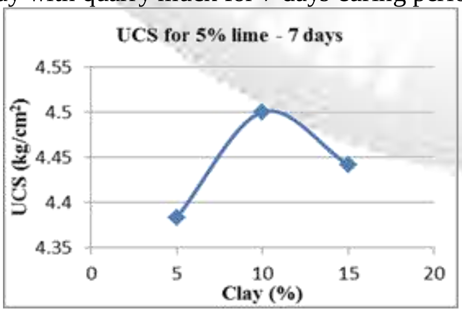

Fig. 12: UCS values for 5% lime and varying percentage clay with quarry muck for 7 days curing period.

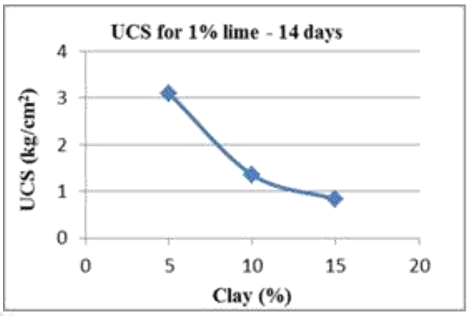

Fig. 13: UCS values for 1% lime and varying percentage clay with quarry muck for 14 days curing period.

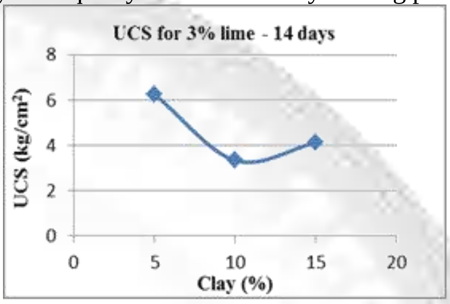

Fig. 14: UCS values for 3% lime and varying percentage clay with quarry muck for 14 days curing period.

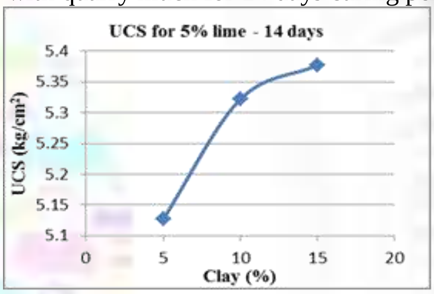

Fig. 15: UCS values for 5% lime and varying percentage clay with quarry muck for 14 days curing period.

C. California Bearing Ratio test

This test was used to assess the strength of the lime and clay on quarry muck sample. The test involves compacting the specimen mixture in the CBR mould at the optimum moisture content determined from the compaction test. The plunger of the CBR machine is made to penetrate the compacted mixture. The load at each penetration is recorded and the CBR is calculated.

The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of natural ground and subgrades beneath new carriageway construction. From the Figure 4.4, it is clear that CBR value at 2.5mm penetration is 6.92% and CBR value at 5mm is 7.34%. Therefore, it can be concluded that the CBR value of quarry muck sample is 7.34%.

The Figs. 16 to 24 shows the un-soaked and soaked California Bearing Ratio values of the 1%, 3% and 5% lime with varying percentage of clay on 0, 7 and 14 days. The maximum California Bearing Ratio value of 14.68 % was obtained for the mixture of 3% lime and5% clay stabilized with quarry muck. The analysis of soaked CBR values for 7 days indicates that the treatment with 1% and 3% lime results in decrement whereas 5% lime treatment shows a steady increase in the soaked CBR values with varying percentages of clay. The maximum soaked California Bearing Ratio value was found to be reaching 29.22% for

3% lime and 5% clay stabilized with quarry muck, thereby increasing the strength of un-soaked sample by 1.99 times. The soaked values in case of 14 days shows that the values increases for 1% and 3% lime content sample as lime content increases and then it reduces due to further increment of lime in the samples. Moreover similar decrease in CBR values was shown up to 5% and 10% percentages of clay followed by a slight increase in values on varying percentages of clay.

The overall analysis of all these results indicates that the strength of the soaked samples increases as the number of days increases and the soaked samples have good strength than un-soaked samples. It is also clear from the tests that the sample of 3% lime and 5% clay content with quarry muck gives highest values at each curing period used in this study.

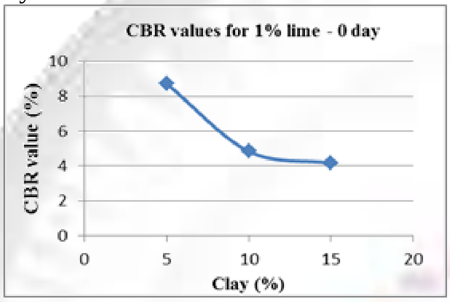

Fig. 16: CBR values for 1% lime and varying percentage of clay with quarry muck.

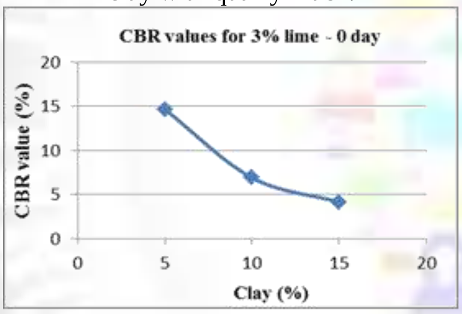

Fig. 17: CBR values for 3% lime and varying percentage of clay with quarry muck.

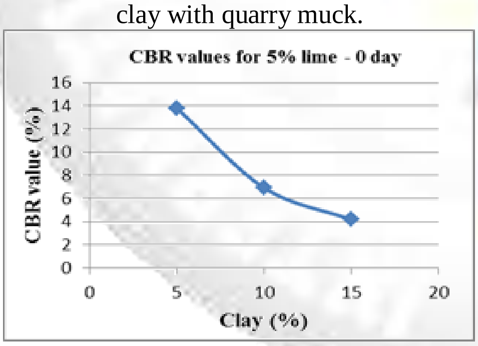

Fig. 18: CBR values for 5% lime and varying percentage of clay with quarry muck.

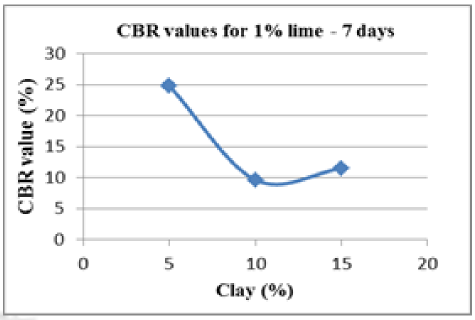

Fig. 19: CBR values for 1% lime and varying percentage of clay with quarry muck for 7 days soaked samples.

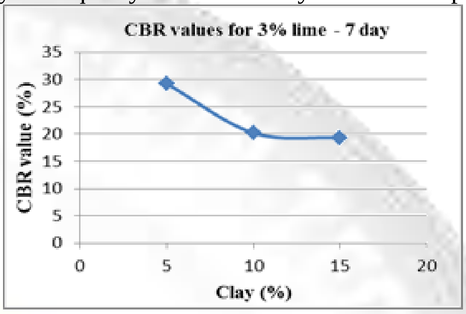

Fig. 20: CBR values for 3% lime and varying percentage of clay with quarry muck for 7 days soaked samples.

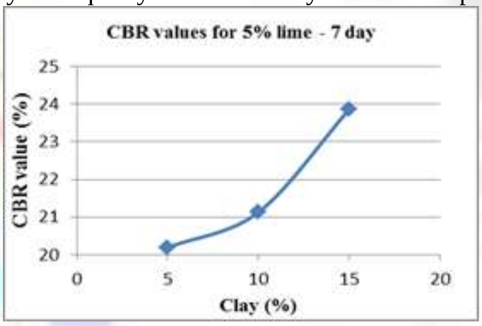

Fig. 21: CBR values for 5% lime and varying percentage of clay with quarry muck for 7 days soaked samples.

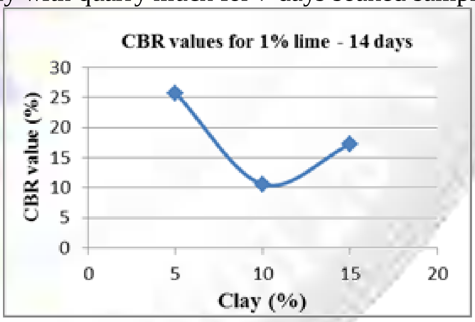

Fig. 22: CBR values for 1% lime and varying percentage of clay with quarry muck for 14 days soaked samples.

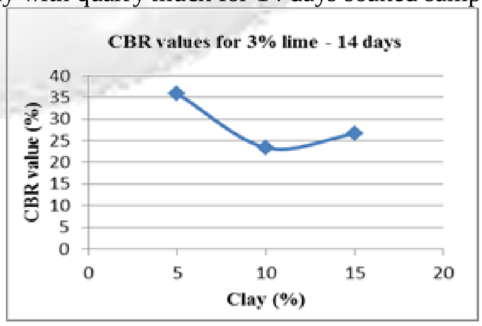

Fig. 23: CBR values for 3% lime and varying percentage of clay with quarry muck for 14 days soaked samples.

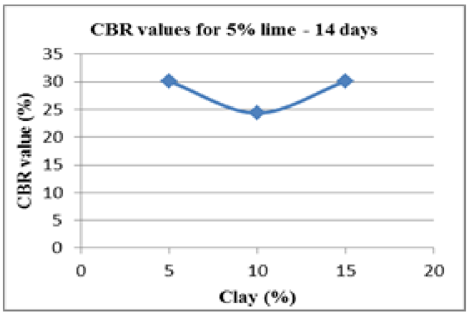

Fig. 24: CBR values for 5% lime and varying percentage of clay with quarry muck for 14 days soaked samples.

D. Direct Shear test

Direct Shear tests are conducted for to determine the shear parameters of various samples. Shear parameters are Shear strength, Cohesion and Angle of internal friction. The shear strength of a soil depends of its resistance to shearing stresses. Cohesion is due to adhesion between the soil particles and Angle of internal friction is due to friction between individual particles.

The test is performed on all the 9 specimens used in this study. A specimen is placed in a shear box which has two stacked rings to hold the sample; the contact between the two rings is at approximately the mid-height of the sample. A confining stress is applied vertically to the specimen, and the upper ring is pulled laterally until the sample fails, or through a specified strain. The load applied and the strain induced is recorded at frequent intervals to determine a stress–strain curve for each confining stress. Several specimens are tested at varying confining stresses to determine the shear strength parameters, the soil cohesion (c) and the angle of internal friction (ϕ). The results of the tests on each specimen are plotted on a graph with the peak (or residual) stress on the y-axis and the confining stress on the x-axis. The y-intercept of the curve which fits the test results is the cohesion, and the slope of the line or curve is the friction angle. The summary of results obtained from different specimens of shear strength parameters are displayed in Table 5 and Table 6.

Samples	Cohesion, c (kg/cm^2)
Quarry muck only	0.38
Quarry muck + 1% Lime + 5% Clay	0.39
Quarry muck + 3% Lime + 5% Clay	0.41
Quarry muck + 5% Lime + 5% Clay	0.42
Quarry muck + 1% Lime + 10% Clay	0.425
Quarry muck + 3% Lime + 10% Clay	0.43
Quarry muck + 5% Lime + 10% Clay	0.45
Quarry muck + 1% Lime + 15% Clay	0.45
Quarry muck + 3% Lime + 15% Clay	0.46
Quarry muck + 5% Lime + 15% Clay	0.48

Table 5: Cohesion values of tested samples

Table 5 shows the cohesion values for varying percentage of lime and clay with quarry muck. Here cohesion values are increased with increasing percentage of lime and clay stabilized quarry muck due to the bonding of particles into larger aggregates such that the soil behaved as a coarse-grained, strongly bonded, particulate material or due to cementation and pozzolanic reactions.

Samples	Angle of Internal Friction, ϕ
Quarry muck only	8
Quarry muck + 1% Lime + 5% Clay	9.5
Quarry muck + 3% Lime + 5% Clay	13.5
Quarry muck + 5% Lime + 5% Clay	12
Quarry muck + 1% Lime + 10% Clay	11
Quarry muck + 3% Lime + 10% Clay	11
Quarry muck + 5% Lime + 10% Clay	10.5
Quarry muck + 1% Lime + 15% Clay	6
Quarry muck + 3% Lime + 15% Clay	6
Quarry muck + 5% Lime + 15% Clay	6

Table 6: Angle of internal friction for varying percentage of lime and clay with quarry muck.

The Table 6 shows the angle of internal friction of varying percentage of lime and clay with quarry muck. By analyzing the values, we can notice a steady increase in values during additions of lime and clay followed by a steep decrease in the value on increasing the additives.

IV. Discussion

A. Strength Development of Lime treated with clays

The compressibility test results show that the lime treated samples experienced high increase in the constrained modulus during the first week of treatment. This increase is supported by the mineralogical and micro-structural changes. The results obviously shows that the bonds resulted from the reaction of lime with the lateritic soil “kaolinitic clays” are stronger than those formed by the reaction with the swelling soils. The increase in strength of the lime treated clays when compared to the strength of the un-treated clays can be attributed to the aggregation of the treated clays and to the contribution of the new reaction products formed due to the stabilization process. The new compounds formed were identified as carbonates and calcium silicate hydrates (CSH) in the short term, calcium aluminates hydrate (CAH) and calcium aluminum silicate hydrate (CASH).

B. Curing Temperature

High temperature is considered to favor the development of strength in lime-stabilized clays. Naturally, a high curing temperature will increase the solubility of the silicates and aluminates found in clay. The reactivity of lime is closely associated with temperature. Lower temperatures are believed to hinder the rate of formation of cementatious compounds that bind soil aggregates together. For example, at a lower temperature the minimum 14 day period noted will likely increase. Generally samples are stored at temperatures corresponding to field temperatures for comparability. A drop in temperature to below 4°C will retard the occurrence of a pozzolanic reaction. Also the strength of clay increase substantially when the temperature was doubled from 20°C to 40°C. It indicates that the strength of lime-treated clay is enhanced at higher temperatures.

C. Curing Time

Normally, the strength of lime stabilized clay increases as curing time increases. It was observed the most notable increases in strength to occur after 14 days and immediately after mixing and lasting up to 14 days, strength gain is dominated by the modification process. After 14 days there is a marked increase in the maximum compressive strength of the clay. Comparing the different curing periods indicate that a greater strength gain is achievable after 14 days. This observation is useful to avoid premature and costly interventions in the lime-clay reaction process.

V. Conclusion

It is evident that construction projects require soils with sufficiently good engineering properties. However, it has been difficult to find suitable sites for construction or suitable material sites for different construction projects within an economic range. Unsuitable materials with poor engineering properties are frequently encountered and hence it is necessary to improve their properties to make them acceptable for construction. Improvement of soil properties or soil stabilization is a technique introduced many years ago with the main purpose of rendering the soils capable of meeting the requirements of the specific engineering projects.

Lime stabilization is one of the most commonly applied soil improvement techniques in the world. As a result of lime stabilization, clay particles stick to each other and form larger particles. The following changes are observed in the soil in short term: optimum water content values increase, Proctor densities decrease and becomes flatter, plasticity indices reduce, and soaked CBR values increase sharply. Based on the studies, lime has been found to reduce the plasticity indices of the clayey soils and has further been determined to transform the soil into a structure that could be worked on more easily.

In this study it has been found that the specimen containing 3% lime and 5% clay along with quarry muck has shear strength and California Bearing Ratio (CBR) strength and Unconfined Compressive Strength (UCS) are more compared to other specimens. In the case of CBR tests, it was found out that the strength of the soaked samples increases as the number of days increases and the soaked samples have good strength than un-soaked samples. The specimen containing 3% lime and 5% clay along with quarry muck is better as subgrade material. In the case of UCS tests, the strength of the samples is directly proportional to the curing periods. The cohesion values are increasing and angle of internal friction a steady increase in values during additions of lime and clay followed by steep decrease in the value on increasing the additive due to the bonding of particles into larger aggregates such that the soil behaved as a coarse-grained, strongly bonded, particulate material or due to cementation and pozzolanic reactions.

References

[1] Abdelmadjid, L., and Muzahim, A-L., (2008), "Effect of Hydrated Lime on the engineering behavior and the micro structure of highly expansive clay", International Association for Computer Methods and Advances in Geomechanics (IACMAG), vol. 04, pp. 3590-3598.

[2] Agus, S, M., Anita, W., Edi, H., and Wilis, D., (2013), "Engineering Properties of Silty Soil Stabilized with Lime and Rice Husk Ash", Journal of Materials in Civil Engineering, vol. 25, pp. 1260-1270.

[3] Akayuli, C., Ofosu, B., Nyako, S. O., and Opuni, K. O., (2013), "The influence of observed clay content on shear strength and compressibility of residual sandy soils", International Journal of Engineering Research and Applications (IJERA), vol. 3, pp. 2538-2542.

[4] Alrubaye, A, J., Hasan, M., and Fattah, M.Y., (2016), "Engineering properties of Clayey Soil Stabilized with Lime", ARPN Journal of Engineering and Applied Sciences, vol.11, pp. 2434-2441.

[5] Balasubramaniam, B., Bolton, M. W.,Buessucesco, B., and Erwin, O., (2008), "Undrained behavior of Lime treated soft clays", Proceedings of the Eighteenth International Offshore and Polar Engineering Conference, pp. 960-965.

[6] Bekki, H., Djilaili, Z., Tlidji, Y., and Daouadji, T, H., (2015), "Durability of treated silty soil using lime and cement in road construction – a comparative study", The Online Journal of Science and Technology, vol. 5, pp. 23-31.

[7] Chandak, N, R.,Babu, A., (2015), "Effect of Lime sludge on strength and compaction of soil", Journal of Civil Engineering Research, vol. 5, pp.18-20.

[8] Choquette, M., Berube, M-A., and Locat, J., (1990), "Laboratory investigations on the lime stabilization of sensitive clays: shear strength development", Geotechnical Conference, vol. 27, pp. 294-304.

[9] Diouf, B., Skidmore, E, L., Layton, J, B. and Hagen, L, J., (1990), "Stabilizing fine sand by adding clay", Soil Technology, vol. 3, pp. 21-31.

[10] Harichane, K., Ghrici, M., and Kenai, S., (2012), "Effect of the combination of lime and natural pozzolana on the compaction and strength of soft clayey soils: preliminary study", Journal of Environmental Earth Science, vol. 6, pp. 2197-2205.

[11] Jawad, I. T., Thaha, M. R., Majeed, Z. H., and Khan, T. A., (2014), "Soil stabilization using lime: Advantages, Disadvantages and proposing a potential alternative", Research Journal of Applied Sciences, Engineering and Technology, vol. 8, pp. 510-520.

[12] Ling, N. L. F., Kassim, K. A., Karim, A. T. A., and Ho S. C., (2014), "Evaluation of contributing factors on strength development of lime stabilized artificial organic soils using statistical design of experiment approach", Advanced Material Research, vol. 905, pp. 362-368.

[13] Liu, M. D., Pemberton, S., and Indraratna, B., (2010), "A study on the strength of lime treated soft clays", International Symposium and Exhibition on Geotechnical and Geosynthetics Engineering: Challenges and Opportunities on Climate change, pp. 245-251.

[14] Nasrizar, A. A., Muttharam, M., and Ilamparuthi, K., (2010), "Role of lime content on soil lime reaction under thermal curing", Indian Geotechnical Conference, pp. 595-598.

[15] Negi, A, S., Faizan, M.,Siddharth, P, D., and Singh, R., (2013), "Soil Stabilization using Lime", International Journal of Innovative Research in Science, Engineering and Technology, vol. 2, pp. 448-453.

[16] Ogundipe, and Moses, O., (2013), "An investigation into the use of lime-stabilized clay as subgrade

material", International Journal of Science and Technology, vol. 02, pp. 82-86.

[17] Parham, R., Younes, D., Mohammad, R. A., Masoud, K. and Ali, T.,(2015), "The potential of Lime and Grand Granulated Blast Furnace Slag Mixture for stabilization of desert silty sands", Journal of Civil Engineering Research, vol. 2, pp. 108-119.

[18] Peterfalvi, J.,Primusz, P., Marko, G., Kisfaludi, B., and Kosztka, M.,(2015), "Evaluation of the effect of Lime-Stabilized Subgrade on the performance of an experimental road pavement", Journal of Engineering Research and Studies, vol. 36, pp. 269-282.

[19] Pratibha, P., and Ameta, N.K., (2013), "Stabilization of dune sand with Bentonite and lime", Electronic Journal of Geotechnical Engineering, vol.18, pp. 2667-2674.

[20] Rajak, T. K., and Pal, S. K., (2015), "CBR values of soil mixed with fly ash and lime", International Journal of Engineering Research and Technology (IJERT), vol. 4, pp. 763-768.

[21] Rao, K, D., Anusha, M., Pranav, P, R, T., andVenkatesh, G., (2012), "A Laboratory study on the stabilization of Marine Clay using sawdust and Lime", International Journal of Engineering Science and Advanced Technology, vol. 2, pp. 851-862.

[22] Rao, K. D., Pranav, P. R. T., and Ganja V., (2012), "A laboratory study on the lime and sawdust treated marine clay subgrade flexible pavement under cyclic pressure", International Journal of Engineering and Innovative Technology (IJEIT), vol. 02, pp. 207-210.

[23] Rao, K, D., Rao, G, V, V., and Pranav, P, R, T., (2012), "A laboratory study on the effect of Rice Husk Ash and Lime on the properties of Marine clay", International Journal of Engineering and Innovative Technology, vol. 2, pp. 52-58.

[24] Saeed, K. A. H., Kassim, K. A., HadiNur, and Yunus, N. Z. M., (2013), "Characterization of Hydrated Lime stabilized brown kaolin clay", International Journal of Engineering Research and Technology (IJERT), vol. 2, pp. 3722-3727.

[25] Saeid, A., Chegenizadeh, A., and Nikraz, H.,(2012), "Laboratory Investigation on the Compaction Properties of Lime and Fly Ash Composite", International Conference on Civil and Architectural applications (ICCAA), vol. 05, pp. 79-83.

[26] Shrivastava, D., Singhai, A.K., and Yadav, R.K., (2014), "Effect of Lime and Rice Husk Ash on Index Properties of Black Cotton Soil", International Journal of Engineering Sciences and Research Technology, vol.3, pp. 292-295.

[27] Thian, S,Y., and Lee, C, Y., (2012), "Shear strength behavior of mining sand treated with clay and hydrated lime", International Journal of civil and structural Engineering, vol.3, pp. 57-69.

[28] Wayal, A, S., Ameta, N, K. and Purohit, M., (2012), "Dune sand stabilization using Lime and Bentonite", Journal of Engineering Research and Studies, vol. 3, pp. 58-60.

[29] Yunus, M. Z. N., Marto, A.,Pakir, F., Kasran, K., Jusoh, N. S., and Abdullah, N., (2015), "Performance of Lime-treated marine clay on strength and compressibility characteristics", International Journal of GEOMATE, vol. 8, pp. 1232-1238.

[30] Yunus, N, Z, M., Wanatowski, D., Stace, R., Marto, A., Abdullah R, A., and Mashros, N., (2016), "A short review of the factors influenced Lime-Clay Reactions", Journal of Civil Engineering Research, vol. 19, pp. 8305-8318.